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# Prototype of a cosmic muon detection system based on scintillation counters with MRS APD light readout

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**Abstract**

Scintillation tiles with MRS APD light readout (START) are proposed to be used as basic triggering units of a cosmic muon facility intended for regular tests of all of the numerous ALICE TOF modules in the course of their mass production and exploitation. A prototype 32-channel array of STARTs has been assembled and tested with cosmic rays and beam. With the bias voltage at approximately 50 V, the system has shown operational consistency and homogeneity, almost 100% detection efficiency over the whole surface and intrinsic noise of $10^{-2}$ Hz per detecting unit. If STARTs are to be mass-produced, the cost of a mosaic array is estimated at a moderate level of 3–4 kUSD/m$^2$.


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## 1. Introduction

The time-of-flight (TOF) system is an important component of the ALICE experiment [1]. It is intended to provide the basic information required for particle identification (PID) in central Pb–Pb collisions at energies of about 5.5 TeV per nucleon pair. The ALICE TOF system [2] will be in the shape of a barrel positioned 3.7 m apart from the collision point. It will consist of about 160 000 detecting cells, each measuring $2.5 \times 3.7\,\mathrm{cm}^2$, and will provide an overall time resolution of less than 100 ps. A decade of intensive R&D was devoted to a new TOF technique based on gaseous detectors of parallel plate geometry operated in the avalanche mode. The final design of the ALICE TOF system is based on multi-gap resistive plate chambers (MRPC) [3].

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Mass production of many MRPC strips is laborious. One of the challenges is to test and calibrate all of the TOF elements before they are installed inside the ALICE detector. The only way to perform these tests is to use cosmic particles, which requires construction of a special cosmic ray facility. Scintillation tiles with MRS APD light readout (START) [4] will be used as triggering elements in this facility. A 32-channel prototype of the triggering system has been developed at ITEP and tested at CERN PS.

## 2. Cosmic tests of ALICE TOF modules

Assembled TOF strips will first undergo several tests in air, which will include high voltage tests to check for the absence of excess leakage currents, pulser tests to check pad connection, and gap measurements. Afterwards the strips will be put into their standard positions inside gas-tight module boxes, each capable of storing about $1.4–1.7 \times 10^3$ TOF cells. Further tests will be performed with assembled modules, equipped with electronics and filled with the standard gas mixture [2]. The modules will be of three different types in accordance with the ALICE TOF system design [2]. The test procedure will be the same for all module types. Cosmic tests will be conducted as a two step process: first, the efficiency and noise characteristics of the TOF cells, as well as cross-talks between neighboring cells will be measured, and, second, the timing parameters for all individual cells will be defined. The second step will require an efficient trigger for detecting the minimum ionizing particles (MIP), as represented in this case by cosmic muons.

If MIPs cross three or more independent TOF modules, the timing parameters of all the cells in these modules (slewing correction and time resolution) may be defined due to the algebraic over-determination of such a system. Measurements must therefore be organized so that several TOF modules, operated independently, are placed under simultaneous timing tests. This method has been examined by the INFN Bologna group during tests of several TOF strips and proved to be effective.

In the cosmic ray test facility, up to six TOF modules will be put in a stack, one over another, as is schematically shown in Fig. 1. Narrow gaps between the modules will provide access to the electronics. At the top, at the bottom and in the middle of the facility, three layers of trigger detectors will be positioned in order to detect cosmic particles (reasons for choosing to proceed with three trigger layers are outlined in Appendix). Just above the bottom layer of trigger detectors, an iron filter may be placed so as to distinguish high-energy muons in the cosmic rays. To cover the whole area of any TOF module type, the inner trigger layer must be at least $3\,m^2$ in size. Making the outer trigger layers larger will increase the solid angle and allow the system to detect more particles with inclined tracks, thus accelerating the data acquisition rate. Assuming that external dimensions of the facility are between $3.5 \times 3.5 \times 3.5$ and $4 \times 4 \times 4\,m^3$, sufficient tracking resolution may be provided if dimensions of a single detecting unit in the triggering system are $15 \times 15\,cm^2$.

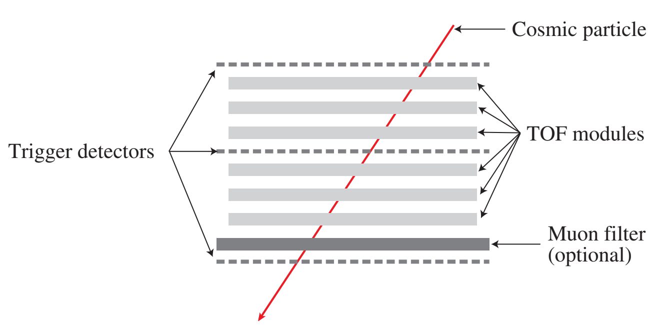

Fig. 1. Organization of the cosmic tests of ALICE TOF modules.

Preliminary simulation of the cosmic test facility was performed to calculate the data acquisition rate and parameters of triggered particles, i.e. their types, momenta and impact angles (see Appendix). The calculated trigger rate was found to be about 200 Hz, which corresponds on average to about 0.1 Hz rate for any cell in any TOF module being tested. This number must be taken into account while planning the acquisition, processing and storage of data.

## 3. Design and performance of START

Scintillation tiles with MRS APD light readout (START) [4] have been chosen as basic triggering elements for the ALICE TOF cosmic ray test facility. These detectors were developed as a result of R&D, performed at ITEP, and have proved to be technologically simple and relatively inexpensive. START represents a scintillating tile-fiber system in which the scintillation light is detected by avalanche photo-diodes (APDs) with a micro-pixel metal-resistor-semiconductor (MRS) structure, operated in the limited Geiger mode. These photo-diodes, called MRS APD,[1] can easily replace traditional photo-multiplying tubes, since they are small, do not require special housing or bulky light-conductors and can be mounted directly inside scintillating plastic plates. There are a number of advantages of MRS APD, such as: its relatively low power consumption, a bias voltage of 50–60 V, single photon sensitivity at room temperatures, intrinsic gain of up to $10^6$, quantum efficiency of 25% in the 'green' region ($520 \pm 10$ nm) and low cost [5]. If the discriminating threshold is set at the level of 3–4 photo-electrons, the noise rate of MRS APD becomes as low as $10^3–10^4$ Hz.

START is assembled from a scintillating tile, two MRS APDs and a piece of optical fiber as shown in Fig. 2[2]. In accordance with the test facility requirements and simulation results, the plastic dimensions have been set equal to $15 \times 15 \times 1.5\,cm^3$. Several types of scintillating plastic have

[1] Developed and produced by CPTA, Moscow, Russia.
[2] Reproduced from Ref. [4].